

# Why the interpretation of “Measuring propagation speed of Coulomb fields” stands

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**Abstract** The experimental findings reported in our original paper de Sangro et al. (Eur. Phys. J. C 75:137, 2015) have been criticized in Shabad (Eur. Phys. J. C 76:508, 2016). We believe that the arguments brought in Shabad (Eur. Phys. J. C 76:508, 2016) are not correct and we show evidence for this.

## 1 Introduction

In Ref. [2], our measurements [1] have been criticized: the authors imply that the responses of our sensors are not caused by the Coulomb field carried by the electron beams, but are rather due to electromagnetic radiation, generated in the last magnetic bend the electron beam undergoes entering the experimental hall. The detail of their main points are:

1. Inconsistencies in our longitudinal timing measurements.
2. Sloping level of background vs. transverse distance for the beam dump measurements.
3. Sensor signals due to synchrotron radiation in the last bend of the beam line.

In the following we will address the stated points separately.

## 2 Longitudinal time measurements

It is clearly stated in our paper [1] (Fig. 13) that no timing dependence on the transverse position of our sensors was measured, and that the correlation timing-longitudinal posi-

tion was the one pertaining to an electron beam moving with  $\gamma \approx 1000$  in the experimental hall. Out of the six measurements reported in Table 1 of Ref. [1], there is just one,  $-2.8\sigma$  away from the above mentioned hypothesis, and is the one that has been speculated upon in Ref. [2]. The authors point out that the measurement might infringe the speed of light barrier. To put things into perspective the  $2.8\sigma$  discrepancy corresponds to less than 150 psec in time or less than 4 cm in space.

We stress that, considering the entire set of data reported in the aforementioned table, one readily sees that timing for sensor A5 tend to be *early* while timing for sensor A6 tend to be *late*. Averaging the timing for A5 and A6, in fact, wipes out completely the fluctuation, and strongly suggests that there be a systematic effect due to a less than perfect flatness of the experimental hall floor. A 35 mrad angle would grant the effect seen in Table 1 of Ref. [1].

We summarize the time distance correlations in Table 1, where the sensors' A5, A6 *average* time obtained at the three different longitudinal positions are shown.

## 3 Sloping background in the beam-dump measurements

No quantitative statement was made in [2] for this effect. In order to have a quantitative understanding of the data, we fit the four point reported in Fig 15 of Ref. [1] either with a constant or with a first order polynomial. A comparison between the  $\frac{\chi^2}{DOF}$  for the two hypotheses might give an insight, in relative terms, as to which one is more suited to represent the data (Table 2).

While it is clear that neither hypothesis fits the data very well, the zeroth order polynomial shows a better agreement to the experimental points; it is worth noticing that the linear function's fitted slope is really ill determined with a relative error close to 80%.

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**Table 1** Timing measurements. The expected differences are calculated for 500 MeV electrons. The agreement between the calculated and the experimental values is more than satisfactory

Longitudinal distances between two sensors (cm)	Expected (ns)	Experimental A5, A6 (ns)
(552.5 – 329.5)	$223.0 \pm 1.5$	$7.43 \pm 0.05$
(552.5 – 172.0)	$380.5 \pm 1.5$	$12.68 \pm 0.05$
(329.5 – 172.0)	$157.5 \pm 1.5$	$5.19 \pm 0.05$

**Table 2** Fit results: flat vs sloping background. Beam dump measurements

	P0	P1	$\frac{\chi^2}{D.O.F.}$
Flat	$0.047 \pm 0.006$	–	2.9
Sloping	$0.038 \pm 0.0098$	$0.004 \pm 0.0034$	3.6

#### 4 Synchrotron radiation out of the last bend

Here too we do not have any quantitative statement in Ref. [2], so we evaluate here the electromagnetic power released in the last bend and compared it with the power of our sensors' signal.

The beam line into the experimental hall has a 45 degrees bend at 1.72 m curvature radius: this translates into a synchrotron radiation (total) power of  $\approx 510 \times 10^{-3}$  W for a typical pulse of  $10^8$  electrons at 500 MeV. The critical frequency for the bend is  $\omega_c \approx 3 \times 10^{17}$  Hz.

We did evaluate the synchrotron radiation power hitting our sensor either with no angular cut or by means of a full Monte Carlo simulation [3] taking into account the angular

**Table 3** Synchrotron radiation summary

	Total power	Power below 250 MHz	Aver. sens. pulse power
No angular cut	$510 \times 10^{-3}$ W	$2 \times 10^{-11}$ W	$1 \times 10^{-6}$ W
Full Monte Carlo	$106 \times 10^{-3}$ W	$4 \times 10^{-12}$ W	$1 \times 10^{-6}$ W

distribution of the emitted radiation at the position of the most exposed detector [radial detector(s) at 5 cm transverse distance and 92 cm. longitudinal distance] As clearly stated in Ref. [1], our sensors have a cut-off frequency of  $\approx 250$  MHz.

The results are summarized in Table 3.

The amount of power synchrotron radiation conveys onto our sensors is at least  $\approx 50,000$  times smaller than the one pertaining to our measured pulse amplitude.

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